Review of venipuncture and intravenous catheterization techniques in pigs

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ABSTRACT

The number of companion pigs in the US is increasing, as is the frequency with which they present to primary companion care practices. However, pigs are often an understudied species in veterinary curricula, and many students graduate from veterinary school with minimal porcine handling experience. Coupled with the poor peripheral vascular access associated with pigs, this presents a challenge for many new graduates and other primary care veterinarians seeking to improve their knowledge of porcine handling, anatomy, and medical care. Furthermore, much of the available veterinary literature regarding porcine venous access is dated, limited to technical notes, or inaccessible to many primary care veterinarians. This review aims to supplement this lack of knowledge by discussing techniques in restraint, sedation, venipuncture, and catheterization of companion pigs as a reference for veterinarians and researchers alike.

Keywords: pig, sedation, venipuncture, catheterization, euthanasia

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Introduction

There has been a recent growth in the population of companion pigs in North America over the last few decades, from an estimated 35,000 registered and 200,000 unregistered potbellied pigs in 2002 to over 1 million in the US and Canada today. This has resulted in a marked increase in the presentation of companion pigs to primary and referral veterinary hospitals. While instruction on porcine production medicine topics exists in most veterinary curricula and the veterinary literature, pigs as household companions differ greatly from production pigs in housing, environment, and owner expectations. Furthermore, the increase in presentation of companion pigs to primary care facilities presents a challenge for veterinarians and technical staff to develop a knowledge of porcine anatomy and venipuncture techniques.

To give companion pigs and owners the best care, first-opinion veterinarians may want to familiarize themselves with different methods of restraint, venipuncture, IV catheterization, and euthanasia. Current descriptions of these techniques are often limited to technical notes, unpublished descriptions, and anecdotal accounts between practitioners and their staff. The few peer-reviewed sources available are often outdated or do not have accompanying visual descriptions for venipuncture techniques. This article aims to integrate the various techniques for restraint, venipuncture, IV catheterization, and euthanasia into a cohesive review, with the goal of providing veterinarians with a peer-reviewed resource to ensure quality and humane care for companion porcine patients.

Methods

Restraint

Snare

Commercial pigs are often restrained with the use of a hog snare placed in the mouth behind the upper canine teeth, looped over the snout. The snare is tightened around the maxilla, and the neck is pulled into extension to increase exposure of the ventral neck for venipuncture (Figure 1). This technique is typically only used for production or production-sized pigs, as many clients of companion pigs find this distasteful, and it is not currently recommended by the North American Pet Pig Association.

Pig “boards” or “hurdles”

Another method for manipulation of swine is the use of restraining “pig boards.” In this method, the pig is squeezed against a wall to create a modified chute, allowing access to the cranial, dorsal, and caudal aspects of the patient for administration of sedatives (Figure 1).
Methods of sedative delivery have become mainstream, leading to a prolonged onset and recovery for the patient. Additionally, pigs tend to accumulate body fat, which necessitates sedation via an alternative approach.

Sedation

The Panepinto sling has been especially developed for swine porcine patients. It is a hammock-like structure that allows abdominal ultrasound in amenable patients. Calming and restraining companion pigs, even those not destined for consumption, can sometimes be accomplished intranasally in swine (Figure 1). In pigs not destined for consumption, the semimembranosus and semitendinosus (hamstring) muscles offer an excellent site for IM injection. Sedative injection directly into the nares without a needle attached, but in larger pigs, use of a 7.6-cm (3-inch) catheter with the stylet removed may be required to increase extension and reduce drug loss when the patient lowers the head.

Forking

Calm, domesticated companion pigs can sometimes be moved from standing to lateral by use of a technique known as “forking.” In this method, a fork or plastic back scratcher is used to scratch the skin around the neck, moving in a dorsocaudal direction until the patient begins to lie down, at which point the stimulation is transitioned to a ventrocaudal direction. This technique has proven to be one of the most useful for calming and restraining companion pigs, even allowing abdominal ultrasound in amenable patients.

Sling

Another method for examining and manipulating porcine patients is the use of a sling or hammock. The Panepinto sling has been especially developed for swine and seems to cause minimal stress once the patient is restrained. Homemade adaptations include the use of polyvinyl chloride pipes formed into a frame, a nylon sheet between them, and padded leg-holes cut into the nylon through which the patient’s legs are left to hang.

Sedation

Pigs have few superficial veins, which frequently necessitate sedation via an alternative approach. Additionally, pigs tend to accumulate body fat, which further complicates delivery of sedatives into muscle. Administration of sedatives into fat is associated with a prolonged onset and recovery for the patient. Four methods of sedative delivery have become mainstream in pigs: intranasal, IM behind the ear, IM in the hamstring muscles, and inhalant delivery via face mask. A summary of sedation and anesthetic protocols is provided (Supplementary Table S1). It is recommended to withhold feed for 12 to 24 hours and water for 4 to 6 hours prior to sedation and anesthesia in nonemergent cases to reduce the risk of aspiration pneumonia.

Intranasal

Administration of sedatives and inoculations of pharmacologic agents for research purposes can be accomplished intranasally in swine (Figure 1). Often, the pigs must have an amenable disposition, be trained to elevate the snout and conditioned to the handlers, or be restrained with a hog snare to keep the snout elevated during administration, making this approach less desirable when dealing with intractable patients. In small pigs, administration of sedatives can be accomplished via syringe injection directly into the nares without a needle attached, but in larger pigs, use of a 7.6-cm (3-inch) catheter with the stylet removed may be required to increase extension and reduce drug loss when the patient lowers the head.

Caudal auricular

Pigs have a relatively low tendency to deposit fat behind the ear compared to other parts of their anatomy, making the ear an excellent site for IM administration of sedatives. This can be accomplished with an 18- to 20-gauge, 2.5- to 3.8-cm (1- to 1.5-inch) needle approximately 1 to 2 cm caudal to the base of the pinna and approximately 5 cm off midline (Figure 1).

Hamstrings

In pigs not destined for consumption, the semimembranosus and semitendinosus (hamstring) muscles offer an excellent site for IM injection. This can be accomplished with an 18- to 20-gauge, 2.5- to 3.8-cm (1- to 1.5-inch) needle 2 to 5 cm distal to the tuber ischii and 2 to 5 cm lateral to the skin on the medial aspect of the femur, depending on the size of the patient. This site should be avoided in pigs destined for human consumption, however, as it may increase the formation of scar tissue in this area and decrease profits for the producer (Figure 1).

Face mask

In rare cases where the porcine patient is conditioned to people and amenable to having the face touched (typically in a nonproduction setting), direct delivery of inhalant anesthetics via face mask can be accomplished. The authors have used this technique with limited success by distracting the pig with peanut butter placed at the narrow-most portion of the face mask, encouraging the pig to breathe the inhalant while slightly disguising the smell of the inhalant. Success of this technique can be improved by clients conditioning their pigs to the touching of the face, nose, and ears from a young age, as recommended by the North American Pet Pig Association.

Monitoring

Following sedation, monitoring vital parameters of the physical examination is of paramount importance. Pigs are predisposed to upper airway obstruction...
following sedation, and placement of an endotracheal tube may be required to ensure airway patency. Tracheal intubation in swine is complicated by the pig’s narrow oral cavity, the width and thickness of the tongue, the elongated epiglottis, and the obtuse angle the trachea makes with the larynx. Furthermore, the dorsal pharyngeal diverticulum and median laryngeal ventricle present obstacles in which the tip of the endotracheal tube can become lodged.

In large (> 360-kg [800-lb]) pigs, the authors have also used endoscopy to guide endotracheal tube placement, as well as digital palpation techniques described for ruminants. The endotracheal tube can then be secured to the snout. Common endotracheal tube sizes range from 3- to 4-mm internal diameter for pigs less than 10 kg to 16-mm internal diameter for pigs over 100 kg.

**Venipuncture**

In production pigs, venipuncture can frequently be performed unsedated by use of restraint by knowledgeable handlers. In a companion animal setting, however, knowledgeable handlers and adequate restraint may not be available, and unsedated venipuncture often results in struggling and vocalization, which can be stressful to both patient and client. Therefore, most venipuncture techniques in companion pigs are performed following sedation. Relative difficulty, blood volumes, positioning, needle sizes, and landmarks for the various venipuncture techniques are summarized (Table 1). Many of the

Table 1—Relative difficulty (ranging from easy [+] to difficult [+++++]), positioning, needle sizes, and landmarks for the discussed venipuncture and catheterization techniques.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Relative difficulty</th>
<th>Positioning</th>
<th>Needle size</th>
<th>Landmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venipuncture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbital sinus</td>
<td>+</td>
<td>Lateral</td>
<td>16-20 ga, 3.8 cm (1.5 inches)</td>
<td>45° angle to third eyelid Aim toward contralateral mandible</td>
</tr>
<tr>
<td>Cranial vena cava</td>
<td>++</td>
<td>Standing, lateral</td>
<td>14-18 ga, 5-17.8 cm (2-7 inches)</td>
<td>1 cm cranial and 1 cm lateral to manubrium Aim dorsocaudomedially toward point between both scapulae Imaginary line between both shoulders and manubrium Insert needle halfway along imaginary line extending from manubrium 45° to right scapula 90° angle to skin Perpendicular to skin Hit coccygeal vertebra, withdraw, aspirate</td>
</tr>
<tr>
<td>Brachiocephalic</td>
<td>+++</td>
<td>Standing, neck extended</td>
<td>18 ga, 5-7.6 cm (2-3 inches)</td>
<td></td>
</tr>
<tr>
<td>Coccygeal vein</td>
<td>+</td>
<td>Sternal</td>
<td>20-25 ga, 2.5 cm (1 inch)</td>
<td></td>
</tr>
<tr>
<td>Catheterization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auricular</td>
<td></td>
<td>Lateral, sternal</td>
<td>18-22 ga</td>
<td>Doroscaudal border of ear</td>
</tr>
<tr>
<td>Jugular (noninvasive)</td>
<td>+++</td>
<td>Dorsal</td>
<td>21 ga</td>
<td>0.5 inch cranial, 0.5 inch lateral to manubrium</td>
</tr>
<tr>
<td>Jugular (cutdown)</td>
<td>+</td>
<td>Dorsal</td>
<td>16-22 ga</td>
<td>2-inch incision, 1 inch lateral of triangle between manubrium and mandibular rami</td>
</tr>
<tr>
<td>Jugular (tracheostomy)</td>
<td>+++</td>
<td>Dorsal</td>
<td>16-22 ga</td>
<td>2- to 5-inch incision on midline Retract trachea/muscles medially to expose jugular vein</td>
</tr>
<tr>
<td>Cephalic</td>
<td>+++</td>
<td>Lateral</td>
<td>18-20 ga</td>
<td>Halfway between radial carpal bone and accessory carpal bone to mammary chain</td>
</tr>
<tr>
<td>Superficial epigastric</td>
<td>+</td>
<td>Lateral, dorsal</td>
<td>16-20 ga</td>
<td>To expose trachea/muscles medially</td>
</tr>
<tr>
<td>Saphenous, lateral</td>
<td>++++</td>
<td>Lateral, contralateral limb elevated</td>
<td>20-25 ga</td>
<td>Between tibial epicondyle and calcaneus</td>
</tr>
<tr>
<td>Saphenous, medial</td>
<td>++++</td>
<td>Lateral, contralateral limb elevated</td>
<td>20-25 ga</td>
<td>Cranial to calcaneus</td>
</tr>
<tr>
<td>Intraosseous</td>
<td>+</td>
<td>Lateral</td>
<td>18-ga, 3.8 cm (1.5-inch) needle (14-ga stylet)</td>
<td>Palpable tubercle of humerus Palpable trochanteric fossa of femur 1 cm proximal to costochondral junction Caudal to border of triceps 1 cm left and 1 cm caudal to xiphoid process 45° angle to skin, aiming cranially</td>
</tr>
<tr>
<td>Intracardiac puncture, lateral approach (euthanasia only)</td>
<td>+</td>
<td>Lateral</td>
<td>14-ga stylet</td>
<td></td>
</tr>
<tr>
<td>Intracardiac puncture, dorsal approach (euthanasia only)</td>
<td>+</td>
<td>Dorsal</td>
<td>14-ga stylet</td>
<td></td>
</tr>
</tbody>
</table>

ga = Gauge.
sites used for venipuncture can also be used for placement of IV catheters and are therefore discussed later in the catheterization section. If the venipuncture site is dirty, cleaning with antiseptic solution followed by alcohol or saline is advised to reduce risk of contamination.

**Orbital sinus**

Blood aspiration from the orbital sinus is fast and minimally invasive and requires minimal training. The patient can be restrained standing with a hog snare or in lateral or dorsal recumbency following heavy sedation. An 18- to 20-gauge, 2.5- to 3.8-cm (1- to 1.5-inch) needle is inserted deep to the nictitating membrane (third eyelid) at a 45° angle toward the contralateral mandible until it hits the lacrimal bone. The needle is then slightly withdrawn and rotated, and a syringe can be attached and used to gently aspirate 5 to 10 mL of blood in an adult pig (Figure 2).

![Figure 2](image_url)

**Figure 2**—Sites for venipuncture in the pig. A—Schematic representation of locations for blood aspiration from the orbital sinus (red arrow), cranial vena cava (solid black arrow), brachycephalic vein (dashed black arrow), and coccygeal vein (blue arrow). B—Projected needle direction for aspiration of blood from the orbital sinus. C—A 20-gauge, 1- to 1.5-inch needle is inserted deep to the third eyelid, at a 45° angle toward the contralateral mandible. D—Landmarks for aspiration of blood from the cranial vena cava. An 18-gauge, 1- to 3-inch spinal needle is inserted in the right thoracic inlet (black caret) lateral to the manubrium of the sternum (black asterisk). E—Projected needle direction (dorsocaudomedial) for venipuncture of the cranial vena cava; the asterisk represents the manubrium of the sternum. F—The needle is oriented aiming at a point (open circle) between the dorsal aspects of both scapulae (paired black lines). G and H—Landmarks for aspiration of blood from the brachiocephalic vein. The pig is restrained standing or in sternal recumbency with the neck extended. Imaginary lines are drawn between both shoulders and the manubrium (asterisk) of the sternum (line 1) and a second line projecting 45° dorsolaterally from the manubrium toward the right scapula (line 2). An 18-gauge, 1.5- to 3-inch needle is inserted in the right jugular fossa (white V) halfway along the second line, perpendicular to the skin. I—Venipuncture of the coccygeal vein. The needle is inserted on midline perpendicular to the skin until it contacts a coccygeal vertebra, then is withdrawn slightly, and blood is aspirated. In large (> 40-kg) pigs, this can be done in lateral or dorsal recumbency (shown here); in smaller (< 40-kg) pigs, sternal recumbency with the tail lifted is recommended. Image created with BioRender.com.
**Cranial vena cava**

Venipuncture of the cranial vena cava is performed without direct visualization of the vessel and can be performed with the patient standing under restraint via hog snare, in sternal recumbency following sedation with an assistant holding the head, or in lateral recumbency following sedation.\(^5\) Large volumes of blood can be obtained with this technique, which is often used for blood collection for transfusion. An 18-gauge, 5- to 7.6-cm (2- to 3-inch) needle (or longer catheter in larger pigs) is inserted in the right thoracic inlet, lateral to the paipable manubrium (Figure 2). The needle is oriented in a dorsocaudomedial direction toward an imaginary point located between the dorsalmost aspect of both scapulae. It is important for the head and neck to be kept straight during this procedure. In rare instances, this technique has been associated with laceration of the cranial vena cava or cardiac tamponade, and for this reason, some clinicians prefer venipuncture of the brachiocephalic vein.\(^5\)

**Brachiocephalic vein**

Venipuncture of the brachiocephalic vein is considerably more difficult and requires a thorough knowledge of porcine anatomy.\(^6\) Similar to the cranial vena cava, large volumes of blood can be obtained with this technique (12 to 20 mL in pigs weighing up to 90 kg).\(^7\) The pig is restrained with a hog snare in a standing position with the neck extended (Figure 2). An imaginary line is traced between the shoulders and manubrium of the sternum, parallel to the ground. A second imaginary line is drawn originating at the manubrium and projecting dorsolaterally at 45° to the right scapula. An 18-gauge, 5- to 7.6-cm (2- to 3-inch) needle is inserted in the deepest part of the right jugular fossa at a point approximately halfway along this second line at a 90° angle to the skin. This technique has been infrequently associated with puncture of the carotid artery and trachea.\(^8\)

**Coccygeal vein**

The coccygeal or “tail” vein represents a relatively easy method to obtain small (1- to 3-mL) volumes of blood in pigs older than 2 weeks of age. The pig is restrained standing or in sternal recumbency following sedation, with the tail elevated by an assistant. A 20- to 25-gauge, 2.5-cm (1-inch) needle or butterfly catheter is advanced perpendicular to the skin until blood is aspirated (Figure 2). The patient is required during aspiration to prevent collapse of the coccygeal vein.

**Catheterization**

Maintenance of IV catheters in pigs can be challenging. The hair at the chosen site should be clipped carefully, as many pigs have sensitive skin and will develop razor burn. The site should be aseptically prepared to reduce risk of infection at the site. The pig’s thick skin must often be “nicked” with a needle, or incised (“cutdown”) with a scalpel blade, to reduce drag of the catheter during IV placement. Relative difficulty, positioning, catheter sizes, and landmarks for the various catheterization techniques are summarized (Table 1).

**Lateral auricular catheterization**

Catheterization of the lateral auricular vein is easy and particularly useful for anesthesia or blood sampling of small (1- to 3-mL) volumes.\(^6\) The patient is restrained standing or in sternal recumbency after sedation. The vein is easily visualized at the dorso-caudal border of the ear and can be distended with digital pressure or by use of a rubber band placed around the base of the ear as a tourniquet to facilitate venous distension. In cases of pigs with dark pigmentation of the ears (eg, Vietnamese potbellied pigs), a light can be shined through the underside of the ear to help visualize the vessels. Use of the bevel of an 18-gauge needle to cut the thick skin of the ear over the vein is encouraged to reduce resistance of the skin against placement of the IV catheter. An 18- to 22-gauge catheter is inserted at a 45° angle to the skin until blood is aspirated (Figure 3). The catheter is then leveled parallel with the skin and advanced to confirm adequate blood flow. The catheter can then be pushed off the stylet, capped, and secured in place on the dorsal pinna with skin glue. Placement of a 6- to 20-mL syringe case in the ear canal can be used to provide mechanical support, and the catheter is taped in place with medical tape. Removal of the tourniquet is of paramount importance, and the authors recommend using a rubber band of a different color than the pig’s skin, as well as inclusion of tourniquet removal on any preoperative checklist.

**Jugular catheterization**

Three techniques have been described for catheterization of the jugular vein in pigs: the noninvasive cutdown, open cutdown, and jugular catheterization following tracheostomy. These techniques are typically used in referral hospitals or for research purposes. The jugular vein runs approximately 1 cm lateral to an imaginary triangle drawn between the angles of the mandible and the sternum (Figure 3).

**Noninvasive (“over-the-wire”)**—This method was first described for research piglets under 2 weeks of age.\(^9\) Piglets are anesthetized with inhalant anesthesia and laid in dorsal recumbency, and a 21-gauge access needle (Vacutainer; Becton, Dickinson and Co) is inserted 0.5 to 1.5 cm (0.2 to 0.5 inches) cranial to the manubrium of the sternum and 0.5 to 1 cm (0.2 to 0.4 inches) lateral to midline. Following aspiration of blood, a 0.071-mm-diameter guide wire is placed through the needle, the needle is withdrawn leaving the wire inside the jugular vein, and the catheter is slid over the wire into the jugular vein. The guide wire is removed, and the catheter is secured in place with skin glue or suture. Repeated sampling of blood has been reported up to 5 days without incident.\(^10\)

**Surgical (“cutdown”)**—Surgical cannulation of the external jugular vein is simple and effective and can often be maintained in pigs that are hospitalized.
A 1- to 5-cm skin incision is made with a scalpel blade, centered 1 to 3 cm lateral to an imaginary line drawn between the manubrium of the sternum and the ramus of the mandible (Figure 3). The fat is bluntly dissected with Mayo scissors until the external jugular vein is reached. The vein can then be catheterized with a 16- to 22-gauge catheter or by use of an over-the-wire technique as described for the noninvasive jugular approach. Ultrasound guidance is also particularly helpful and can avoid the need for a large surgical incision.21,22

**Following tracheostomy**—In terminal research cases involving anesthesia, it is often easier to perform a tracheostomy following sedation to bypass intubation difficulties associated with the laryngeal ventricle in pigs. If this is the case, catheterization of the internal jugular vein can be performed through the same incision. To perform the tracheostomy, the pig is anesthetized and placed in dorsal recumbency, and a 5- to 10-cm incision is made on midline beginning 1 to 2 cm cranial to the manubrium of the sternum and extending cranially (Figure 3). The paired sternohyoideus muscles are bluntly separated and retracted to reveal the trachea. An incision is made on the ventral aspect of the trachea between the second and third cartilaginous rings, extending no more than half the diameter of the trachea. An endotracheal tube can then be inserted to maintain adequate depth of anesthesia for jugular catheter placement. While pigs have been extensively used as a large animal model for teaching tracheostomy to otorhinolaryngologists,23–26 these studies typically result in the euthanasia of these pigs, and the long-term effects of tracheostomy in pigs are unknown.

Following tracheostomy, the trachea and sternohyoideus muscles are retracted medially to expose the carotid artery and jugular vein, which lie dorsal and lateral to the trachea. Catheterization of the jugular vein can then be performed as described by use of either the noninvasive or cutdown techniques previously described. This approach risks damage to the...
laryngeal nerves and results in decreased mucociliary transport and is therefore only recommended for terminal cases.

**Cephalic catheterization**

The cephalic vein is located on the medial aspect of the thoracic limb and represents a moderate difficulty in catheterizing pigs due to the presence of venous valves. The pig is restrained in lateral recumbency following heavy sedation or anesthesia. A tourniquet is applied proximal to the elbow. Venipuncture can be achieved by inserting an 18- to 20-gauge, 3.8-cm (1.5-inch) needle on the medial aspect of the limb equidistant between the radial carpal bone and the accessory carpal bone where the cephalic vein dives deep to the thick carpal fascia (Figure 3) or more proximally where it crosses the cranial aspect of the limb, though it is difficult to apply a tourniquet in the latter location. Catheterization can be achieved at the level of the carpus, with either traditional companion animal catheters or with over-the-wire kits previously described. Frequently, the wire from over-the-wire catheter kits has a 180° bend that can become entangled in the venous valves of the pig; it is recommended to remove this wire from its plastic guide, reverse its direction, and place it back in the wire guide backwards so that the end of the wire being fed through the guide and into the pig is straight, reducing the risk of valve entanglement.

**Subcutaneous abdominal (superficial epigastric) vein**

The superficial epigastric vein is one of the more easily managed approaches for IV therapy in larger (15- to 40-kg) pigs. Following sedation or anesthesia, the pig is placed in lateral recumbency. For venipuncture, the vein is distended by use of manual compression behind the elbow. An 18- to 20-gauge needle is inserted into the vein oriented cranially, and 10 to 20 mL of blood can be aspirated gently. Care must be taken to avoid entry into the peritoneal cavity. For catheterization, a 1- to 5-cm incision is made 3 to 5 cm lateral to the mammary chain (Figure 3). The vein is catheterized with an 18- to 22-gauge catheter by use of traditional companion animal IV catheters or an over-the-wire technique as described for the jugular vein. Ultrasound guidance can be particularly useful in obese patients.

**Saphenous**

Venipuncture and catheterization of the saphenous vein is more commonly performed in traditional companion animals where the skin is not as thick as it is in pigs; however, both the lateral and medial saphenous veins offer moderate venous access in the porcine patient.

**Lateral saphenous**—The lateral saphenous vein is moderately difficult for venipuncture and markedly difficult to catheterize due to the presence of valves within the vein and is typically recommended for older (> 2-year-old) and larger (> 40-kg) pigs. The vein ascends from the lateral portion of the pelvic limb between the fourth and fifth metatarsal bones and crosses the tarsus just cranial to the calcaneal tuberosity (Figure 3). Venipuncture can be performed with a 20- to 25-gauge needle or butterfly catheter, and catheterization should be performed by use of an over-the-wire technique, but with the wire reversed as described for the cephalic vein.

**Medial saphenous**—The medial saphenous vein is somewhat more easily accessible than its lateral counterpart. The vein ascends on the medial aspect of the pelvic limb between the second and third metatarsal bones and crosses deep to a thick layer of tarsal fascia before coursing cranially and proximally (Figure 3). Venipuncture can be performed with a 20- to 25-gauge needle or butterfly catheter just cranial to the calcaneus, and catheterization should be performed by use of an over-the-wire technique, but with the wire reversed as described for the cephalic vein.

**Intraosseous**

In cases where there is immediate need for vascular access but an IV catheter has not been established, intramedullary cannulation should be considered. The greater tubercle of the humerus and the trochanteric fossa of the femur can easily be penetrated with an 18-gauge, 3.8-cm (1.5-inch) needle (Supplementary Figure S1). Repeated sampling of blood from the proximomedial region of the tibia was shown to be safe in young (< 10-week-old), healthy pigs, and hematologic values correlated well with blood obtained from peripheral (caudal auricular) sites. Fluid administration is easily and safely performed in young pigs, but older pigs may have increased fat and fibrosis of the medullary canal, limiting rate of fluid administration. Additionally, 33% of pigs developed coronary fat emboli and 100% developed pulmonary fat emboli in a porcine hemorrhagic shock model, suggesting that alternative fluid administration routes (eg, per rectum) may be preferable in these patients.

**Euthanasia**

Methods for euthanizing pigs approved by the AVMA include gunshot, penetrating captive bolt, electrocution, and barbiturate overdose. Other techniques include exsanguination or use of inhaled gases (CO₂, N₂, Ar) but are not appropriate as sole methods of euthanasia and require the patient to be unconscious. Since the only technique to require venous access is the administration of barbiturates, it is the only method of euthanasia that will be discussed here.

Intravenous injection of barbiturates can be used at a dose of 1 mL/kg up to 30 kg, then 1 mL for every 10 kg of patient body weight thereafter, to induce brain death. Injection can be performed through any of the catheter techniques described previously (though administration of large volumes may be technically difficult, especially through auricular catheters), or via intracardiac injection. Auscultation and palpation for the apex beat are recommended for ensuring accuracy and success on first attempt. Care should be taken to ensure an adequate
level of sedation or plane of anesthesia prior to intracardiac injection. There are 2 approaches to perform intracardiac injection of euthanasia solution in pigs.

**Lateral approach**

For the lateral approach, the pig is placed in lateral recumbency, ideally on the right side. A large-bore (14-gauge) catheter, spinal needle, or hollow stylet is inserted into the thorax 1 cm proximal to the costochondral junction just caudal to the palpable border of the triceps muscle (Figure 4) until the catheter/stylet is observed to twitch in synchronous movement with the heartbeat. Blood can often be aspirated at this time but typically does not eject from the needle when the syringe is detached. Injection of the euthanasia solution should be swift and smooth, as if injecting into a joint space. Lack of blood aspiration or difficulty/resistance on injection suggests that the end of the needle is lodged in the pericardium or myocardium, and the needle should be advanced or backed out as needed until blood is aspirated or resistance to injection subsides.

**Ventral approach**

For the ventral approach, the pig is laid in dorsal recumbency, and the needle is inserted at a 45° angle to the skin in a craniodorsal position 1 cm caudal and 1 cm left of the xiphoid process of the sternum (Figure 4). The needle is advanced until synchronous motion is observed as described, and the euthanasia solution is injected.

### Withdrawal intervals

Because pigs are a major food animal species, meat withdrawal intervals should be made available to the client regardless of companionship status. Withdrawal intervals for drugs discussed in this review are summarized (Supplementary Table S2), and clinicians are encouraged to contact the US Food Animal Residue Avoidance Databank with questions (please note that withdrawal intervals may vary by country). Following euthanasia with barbiturates, it is of vital importance that no part of the pig enters the domestic or international food chain for either people or other animals.

### Acknowledgments

None reported.

### Disclosures

No pigs were euthanized for the purpose of this study; all dissections were performed postmortem with IACUC approval for a separate study (No. 21-476).

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Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org.